THE CIRCULATORY SYSTEM

The Functions of the Circulatory System

a. Transport

- Oxygen, CO_2, nutrients, metabolic wastes, and hormones

b. Protection

- Blood plays several roles in inflammation that limits spread of infection
- White blood cells destroy microorganisms and cancer cells
- Antibodies and other blood proteins neutralize toxins and help to destroy pathogens.
- Platelets secrete factors that initiate blood clotting and other processes for minimizing blood loss.

c. Regulation

- the blood capillaries stabilize fluid distribution in the body
- blood proteins stabilize the pH of the extracellular fluids
- dissipating metabolic heat from the body

The structure of the Circulatory System

- The circulatory system consists of the heart, blood vessels, and blood.
  - The heart: the pump that keeps the blood flowing
  - Blood vessels: transport blood throughout the body.
  - Blood: the liquid medium in which materials travel.

1. The Human Heart

- It is a muscular organ that pumps blood through the blood vessels.
  - It is made up of cardiac muscle
  - It is enclosed in a protective coat called pericardium.
- It is reddish-brown in color and is approximately the size of a closed fist.
- It is located between the lungs and has four chambers.
  - The top two chambers are called the right atrium and left atrium.
    - The walls of atria are relatively thin.
    - They receive incoming blood.
  - The bottom two chambers are called the right and left ventricles.
    - The walls of the ventricles are much thicker
    - They pump blood out of the heart.
    - The muscle walls of the left-hand side of the heart are thicker.
- There are four valves in the heart that ensure blood flows in only one direction.

- The atrioventricular valves prevent backflow of blood from the ventricles into the atria.
    - Tricuspid valve: located between the right atrium and the right ventricle.
    - Bicuspid (mitral) valve: located between the left atrium and the left ventricle.
- Semilunar valves are paired valves of the heart at the bases of the aorta and the pulmonary artery.
    - Pulmonary valve: located between the right ventricle and the pulmonary artery.
    - Aortic valve: located between the left ventricle and the aorta.

The Working of the Heart

- Right atrium receives deoxygenated blood from veins
- Right atrium contracts and pumps blood into right ventricle
- The right ventricle pumps deoxygenated blood to the lungs.
- The left atrium receives oxygenated blood from the lungs.
- The left atrium contracts and empties the oxygenated blood into the left ventricle.
- Left ventricle contracts forcing oxygenated blood to the entire body.
- The superior vena cava and inferior vena cava bring deoxygenated blood to the heart

Double Circulation

- In the pulmonary circulation, blood flows from the heart to the lungs and back again.
    - Important to exchange oxygen and carbon dioxide with the air
- In the systemic circulation blood is pumped from the heart all around the body and back again.

Cardiac Cycle

- It a sequence of alternating contraction and relaxation of the atria and ventricles in order to pump blood throughout the body.
    - At rest, the human heart beats 70 times per minute.
    - During physical exercise, the heart beats faster (120–140 beats per minute).
- It consists of two periods.
    - **Diastole**: the heart muscle relaxes and fills with blood
    - **Systole**: Contraction of the heart muscle and pumping of blood
- A normal blood pressure is 120/80 mmHg.
    - The top number (called the systolic pressure) is the force each time the heart beats.
    - The bottom number (diastolic pressure) is the force between beats.
- Blood pressure varies through the day and depending on individuals' activity.
- Blood pressure is most commonly measured via a sphygmomanometer.
    - Blood pressure values are generally reported in millimeters of mercury (mmHg).

2. The Blood Vessels

- The pathways along which the transport takes place
- Three main types of blood vessels: arteries, veins and capillaries
    - ➢ They have different functions in the body

a. The arteries

- carry blood away from the heart
    - ➢ usually oxygenated blood (bright red)
    - ➢ The only arteries that carry deoxygenated blood are the pulmonary arteries and the umbilical artery.
        - ❖ Umbilical artery carries blood away from a foetus into the placenta
- They have thick wall with muscle fibres and elastic tissue
    - ➢ they can stretch as the blood is forced through them
- have a pulse in them
- the blood in the arteries is under pressure

b. The veins

- They carry blood towards the heart
    - ➢ The blood is low in oxygen (deep purple-red colour)
    - ➢ The only veins that carry oxygenated blood are the pulmonary veins and the umbilical vein.
        - ❖ Umbilical vein carries oxygenated blood from the placenta back to the developing foetus.
- They have much thinner walls than arteries
- The blood in them is under much lower pressure
- They do not have a pulse.
- They often have valves to prevent the back-flow of blood.

c. Capillaries

- They are very narrow, thin-walled blood vessels
- They are found between the arteries and the veins
    - ➢ They link the other two types of blood vessels.
- They take the blood into all the organs and tissues of the body.
- Capillaries have very thin walls and a massive surface area.
- The capillaries are the site of the exchange of substances within the body.

3. Blood

- Blood is a circulating tissue.
- It is composed of fluid plasma (55%) and different kinds of cells (about 45%).
- The normal pH of human arterial blood is approximately 7.40.
- An average adult has a blood volume of about 5 liters
    - Blood is about 7% of the human body weight.

a. Plasma

- It is a pale yellow liquid.
- It transports all the blood cells, waste products (CO_2 and urea) and end products of digestion.
- Plasma is about 91.5% water and 8.5% solutes, most of which by weight (7%) are proteins.

b. Red blood cells (Erythrocytes)

- They are the most numerous cells in the blood.
    - There are 4.5–5 million RBCs/mm^3 of blood.
- They are formed in the bone marrow.
- Mature red blood cells are non-nucleated.
    - There is more room to carry extra hemoglobin.
    - They live only 100–120 days.
- They are biconcave disc in shape with a diameter 7.0–8.0µm and thickness of 1.7–2.4µm.
    - They have larger surface area to volume ratio
    - They are relatively thin
    - They have relatively a thin surface membrane
    - They squeeze easily in capillaries (deformable)
- They contain the pigment hemoglobin which has the ability to combine reversibly with O_2.
    - They are primarily involved in tissue respiration.
- RBCs have different antigens on their surfaces.
- In the ABO system, there are antigen A and antigen B.
- There are two possible antibodies in the plasma: anti A and anti B antibodies
    - The antibody that reacts against antigen A is called anti-A; it is present in the plasma of anyone who does not possess antigen A.
    - The antibody that reacts against antigen B is anti-B, and is present in those who do not possess antigen B.
- Before transfusion, the blood groups of the donor and the recipient must be known in order to prevent agglutination.

- In giving transfusions, it is imperative that the donor's RBCs not agglutinate as they enter the recipient's bloodstream.
    - A person with type A (anti-B) blood must never be given a transfusion of type B or AB blood.
    - A person with type B (anti-A) must never receive type A or AB blood.
    - Type O (anti-A and anti-B) individuals cannot safely receive type A, B, or AB blood.

Characteristics	**ABO blood type**			
	Type O	**Type A**	**Type B**	**Type AB**
RBC antigen	Neither A nor B	A	B	Both A and B
Plasma antibody	Anti-A, anti-B	Anti-B	Anti-A	Neither
May safely receive RBCs of	Type O	Type O or A	Type O or B	Type O, A, B, or AB
May safely donate RBCs to	Type O, A, B, or AB	Type A or AB	Type B or AB	Type AB
Possible genotypes	OO	AA, AO	BB, BO	AB

c. White blood cells (Leucocytes)

- They are a heterogeneous group of nucleated cells.
    - Neutrophils, Eosinophils, Basophiles, Lymphocytes and Monocytes.
- They are responsible for the body's defenses.
- They are fewer in number than the red blood cells (5,000–10,000 / mm^3 in adults).
- They are bigger than RBCs
- Their production is in the bone marrow and lymphoid tissues (lymph nodes, lymph nodules and spleen).

d. Plateletes (Thrombocytes)

- They are small, non– nucleated, round/oval cell fragments with a life span of about 10 days.
    - Their size ranges 1–4μm in diameter.
    - They are produced in the bone marrow by fragmentation of cells called megakaryocytes.
- They are much more numerous (150,000 to 400,000 /mm^3) than the WBCs.
- Their primary function is preventing blood loss from hemorrhage.
    - They form a network of protein threads (fibrin)
        - It prevents bleeding to death
        - It prevents the entry of pathogens through open wounds

Common Problems of the Circulatory System

1. Anaemia

- It is a deficiency of either RBCs or hemoglobin.
- The causes of anemia fall into three categories:
  i. inadequate production of red blood cells or hemoglobin synthesis,
  ii. bleeding (hemorrhagic anemia)
  iii. RBC destruction (hemolytic anemia)
- The most common form of nutritional anemia is iron-deficiency anemia.
  - Meat, liver. Apricots, eggs and green leafy vegetables are dietary sources of iron.
- A deficiency of vitamin B_{12} also causes anemia.
- Symptoms are tiredness and lack of energy.
- Anemia has three potential consequences:
  i. The tissues suffer hypoxia (oxygen deprivation).
    - Severe anaemic hypoxia can cause life-threatening death of brain, heart, and kidney tissues.
  ii. Blood osmolarity is reduced resulting in edema (tissue swelling).
    - More fluid transfers from the bloodstream to the intercellular spaces.
  iii. Blood viscosity is reduced.

2. Hypertension (High blood pressure)

- High BP is commonly considered to be a chronic resting blood pressure higher than 140/90.
- It is a "silent killer" and is the major cause of heart failure, stroke, and kidney failure.
- Primary hypertension, which accounts for 90% of cases, results from such a complex web of behavioral, hereditary, and other factors that it is difficult to sort out any specific underlying cause.
- Secondary hypertension, which accounts for about 10% of cases, is high blood pressure that results from other identifiable disorders.
  - chronic kidney diseases, diseases in the arteries supplying the kidneys, chronic alcohol abuse, hormonal disturbances, or tumors.
  - Secondary hypertension is corrected by treating the underlying disease.
- The risk factors are increasing age, being overweight, excessive salt intake, excessive consumption of alcohol, sedentary life style, smoking, kidney diseases, diabetes and certain medicines like steroids
- It can be managed through life style adjustments.
- It is often treated with drugs called diuretics and beta blockers.
  - Diuretics: lower blood volume and pressure by promoting urination.
  - Beta blockers: block the nerves narrowing arteries.

MCQs on "Circulatory System" from EGSECE Biology Examination (2003 – 2014)

1. The transportation of oxygen and nutrients within the human body is facilitated by the (2007)
   A. respiratory system.
   B. circulatory system.
   C. excretory system.
   D. nervous system.
2. Which of the following structure of the heart is correctly matched with its function? (2007)
   A. Left atrium – receives oxygenated blood from the lungs.
   B. Right atrium – contracts and forces blood out to the body.
   C. Left ventricle – contracts and forces the blood out to the lungs.
   D. Right ventricle – receives deoxygenated blood from the body.
3. Which of the following statements is correct about the structure and function of the heart? (2011)
   A. The right atrium collects blood from all parts of the body except the lungs.
   B. The tricuspid valves prevent flow of blood from the atria into ventricles.
   C. The left ventricle forces blood into the pulmonary trunk.
   D. The left atrium pumps blood to the lungs.

   Item number 4 based on the list of the four heart chambers given below.

   1. Left auricle 2. Left ventricle 3. Right auricle 4. Right ventricle
4. Suppose you ingested a chemical substance with your meal which specifically degrades the function of cardiac tissue. In which of the following orders does the degradation takes place? (2003)
   A. 3,1,2,4 B. 1,2,3,4 C. 3,4,1,2 D. 2,4,3,1
5. The valves of the heart play a significant role to (2009)
   A. supply blood to the cardiac muscle and atrium.
   B. allow the transport of blood in the right direction.
   C. transport deoxygenated blood into the lung.
   D. transport oxygenated blood to the rest of the body.
6. What is the cause of the back flow of blood into the atria from the ventricles? It could be damage of the (2014)
   A. aorta.
   B. pulmonary artery.
   C. pulmonary vein.
   D. valves.
7. Which of the following valve structures prevents the back flow of blood into the right auricle when the right ventricle contracts? (2003)
   A. Tricuspid B. Semi-lunar C. Bicuspid D. Mitral
8. This item is based on the following steps of blood transport. (2006)
   A. The right ventricle contracts and forces blood out of the heart into the lung.
   B. Oxygenated blood returns to the left side of the heart and the left atrium fills up.
   C. The left ventricle contracts forcing oxygenated blood out of the heart to around the body.
   D. The left atrium contracts forcing blood into the left ventricle.
   E. Deoxygenated blood comes into the right atrium of the heart from the veins of the body.
   F. The right atrium contracts and forces blood into the right ventricle.

   Which of the following is the correct path of blood in the heart?
   A. E → C → A → D → F → B
   B. E → A → C → D → B → F
   C. E → A → B → F → C → D
   D. E → F → A → B → D → C
9. Suppose the blood pressure of a person is found to be 140/95. Which of the following is true? (2003)
   A. The numerator indicates diastolic pressure.
   B. The denominator is the pressure resulting from contraction of left ventricle
   C. The person has a problem of high blood pressure
   D. The person needs to increase his/her weight

10. If the pulse rate of an adult at rest is 18 times in 15 seconds. What is the pulse rate of this man per minute? (2003)
    A. 90 B. 54 C. 72 D. 108
11. The three types of human blood vessels are (2006)
    A. aorta, vena cava, and capillaries.
    B. artery, vein and capillaries.
    C. hepatic artery, pulmonary artery, and renal artery.
    D. hepatic vein, pulmonary vein, and renal vein.
12. Which of the following functions of blood vessels is true? (2006)
    A. Veins always carry blood towards the heart.
    B. Arteries always carry oxygenated blood.
    C. Pulmonary vein carries deoxygenated blood from lungs to the heart.
    D. Umbilical vein carries deoxygenated blood from placenta to the fetus.
13. Which of the following statements is correct about the human blood vessels? (2007)
    A. Veins always carry deoxygenated blood.
    B. Arteries always carry oxygenated blood.
    C. Capillaries are thicker than veins.
    D. Capillaries link arteries with veins.
14. Blood vessels that carry deoxygenated blood and return it to the heart are (2010)
    A. veins. B. arteries. C. capillaries. D. lymph vessels
15. Which of the following blood vessels is correctly matched with its function? (2011)
    A. Veins – carry blood from other parts of the body to the lung
    B. Arteries – carry blood from the heart to other parts of the body
    C. Capillaries – carry blood from other parts of the body to the heart
    D. Vena cava – carry blood from the heart to other parts of the body
16. The capillaries are blood vessels that have thin wall and large surface area since their function is (2014)
    A. transport of oxygenated blood.
    B. exchange of substances.
    C. to return blood to the heart.
    D. transport of deoxygenated blood.
17. Which of the following blood components transports waste products to the kidneys? (2009)
    A. Platelets
    B. White blood cells
    C. Plasma
    D. Red blood cells
18. The main components of human blood are (2007)
    A. red blood cells, platelets, heart and lymph vessels.
    B. red blood cells, plasma, heart and lymph vessels.
    C. plasma, red blood cells, white blood cells and platelets.
    D. plasma, white blood cells, heart and red blood cells.
19. The following is a list of functions of the components of blood
    1. Transport of oxygen
    2. Fight against diseases
    3. Cause blood clotting

    Which one of the following is a correct order of blood components responsible for the above functions respectively? (2014)
    A. White blood cells, platelets, red blood cells
    B. Platelets, white blood cells, red blood cells
    C. Red blood cells, white blood cells, platelets
    D. Red blood cells. Platelets, white blood cells

20. Red blood cells carry oxygen all over your body and supply it to your body cells. This is because red blood cells have (2006)
    A. hemoglobin. B. antibodies C. nucleus. D. antigens.
21. This item is based on the following list of events about the transport of oxygen into the cell.
    1. Oxygen enters into the cells where it is needed.
    2. Haemoglobin picks up oxygen and form oxyhaemoglobin.
    3. Oxyheamoglobin splits to give purple-red haemoglobin and oxygen.
    4. Oxygen enters into mitochondria for aerobic respiration.

    Which one of the following sequence of events is correct about transport of oxygen into the cell? (2009)
    A. 2→3→1→4 C. 4→3→2→1
    B. 2→3→4→1 D. 1→2→4→3
22. Which of the following blood groups has no antigen on the red blood cells? (2009)
    A. B B. A C. AB D. O
23. Someone, who has blood group "A" has got a car accident and lost a lot of blood. Therefore, he needs blood transfusion. Which of the following blood groups is used during the transfusion? (2007)
    A. AB B. O C. OB D. B
24. On a clean glass slide, a nurse mixed donor's 'AB' blood group with recipients 'B" blood group. What result could she observe after mixing the two blood groups? (2009)
    A. There was no change in appearance.
    B. The red blood cells increased in size.
    C. The color of the mixture changed to blue.
    D. The mixture becomes agglutinated.
25. During delivery, a pregnant woman whose blood type "O" has lost a lot of blood. The doctor ordered her family to get a blood donor. What should be the blood type of the donor? (2009)
    A. O B. AB C. A D. B
26. If a person with blood group "B" loses blood due to an accident, he may receive blood donation from group (2010)
    A. "B" & "O". B. "B" only. C. "AB" only. D. "A" & "B".
27. A woman lost a lot of blood during delivery and the doctor found that she required blood from another person to save her life. Then, he checked her blood type and found that she has a blood type O. Agglutination will not happen if she receives a blood from a person having blood group (2011)
    A. A. B. B. C. AB. D. O.
28. Assume you wanted to demonstrate compatibility of blood groups. You took four test tubes labeled O, A, B, and AB based on the blood group that each test tube contains. Then you added unknown blood sample into each test tube and agglutination was observed in each test tube. From this, you can conclude that the unknown blood sample was (2014)
    A. Blood group B. C. Blood group A.
    B. Blood group O. D. Blood group AB.
29. Anaemia is caused by (2011)
    A. lack of iron in the diet. C. excessive alcohol intake.
    B. excessive salt intake. D. being overweight.
30. Which of the following methods is used to prevent hypertension? (2006)
    A. Eating foods that have iron source C. Doing regular exercise
    B. Eating canned foods D. Using vitamins